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Eastern Gulf of Maine Sentinal Survey Report 2016

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Eastern Gulf of Maine Sentinel Survey 2010-2016

Report[1]

submitted by

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[1] Part of this report repeats the contexts of the draft final report for 2010-2014 because this report is an update of the report for 2010-2014 with an addition of 2015 data

Part One: The Eastern Gulf of Maine Sentinel Survey Fishery: Jigging Report Only 2012-2016

I. Executive summary

The Eastern Gulf of Maine Sentinel Survey/Fishery is a groundfish survey conducted in the summer from the western edge of Penobscot Bay to the eastern border with Canada. The survey consists of stratified random stations that are sampled with both demersal longline gear and jigging gear. A portion of the stations is also allocated for fishermen to select where they want to fish based on their knowledge of historic fishing grounds and suitable habitat. The primary objective of the survey is to provide an annual index of abundance as well as habitat preference information for groundfish species (including Atlantic cod, cusk, white hake and Atlantic halibut) in an area that was traditionally important for the commercial groundfish fishery but is not currently well covered by either commercial fisheries or other bottom-trawl –based monitoring programs. This report focuses on the most recent year of the sentinel survey/fishery in 2016, but also includes an analysis of all the survey/fishery catch data since the inception of the sentinel survey/fishery in 2010 to the most recent year 2016**. Part one of this report focuses on jigging only, because the survey was consolidated to only jigging stations in 2016 due to financial constraints. Part two of this report focuses on the entirety of the Eastern Gulf of Maine Sentinel Survey/Fishery, including both longline and jig gear sampling and original survey design.**

Sampling Effort Allocation

In 2016, the overall allocation of sampling effort consisted of a jig-only stations. This was different than previous years; between 2010-2011 the survey sampling was conducted using longline gear only, and between 2012-2015 the sampling was conducted using both longline and jig gear. However, in 2016 there was a financial constraint that allowed sampling with one gear type only, and in a limited capacity. Therefore, though stations were randomly allocated and stratified by depth just as in previous years, sampling was conducted with jig gear only, and in Strata 0-2 as opposed to Strata 0-3. Because jig gear was the only gear type used to sample survey stations in 2016, the survey became primarily one targeting Atlantic cod, pollock, and mackerel as opposed to a more diverse portfolio of groundfish species. This is because there is low catchability of other species on jig gear. However, jig gear is highly efficient, especially in areas with high gear congestion and rocky, complex bottom habitat structure. This report will focus on results from jig stations between 2012-2016.

There were 62 total randomly selected jig stations sampled in 2016, spanning depths in Strata0-2 (Figure 1). These stations are labeled based on the depths they encompass; all stations in Stratum 0 are called "JJ Stratum 0", and all stations in Strata 1-2 are called "JJO". All random jigging stations together are simply called "JJ". In Stratum 0 (0-50m), there were 36 stations sampled, which made up 50.7% of the total sampling effort (Table 1). There were 9 stations in Stratum 1 (50-80m), which comprised 12.7% of the total sampling effort (Table 1). Stratum 2 (80-150m) contained 17 stations, which made up 23.9% of the total sampling effort for 2016 (Table 1).

In addition to the randomly selected jigging stations, there was also a "fishermen's choice" component included in the overall sampling effort. These stations were selected by fishermen anywhere in the survey area. Therefore, these stations were not part of the stratified random, or "fisheries-independent" design, but were instead considered to be "fisheries-dependent". These stations were also sampled with jigging gear, and spanned depth ranges between 0-150 m. The stations that are considered to be fishermen's choice are labeled as "JF". There were 9 JF stations in 2016, comprising 12.7% of the total sampling effort (Table 1).

There were 47 random stratified jig stations sampled in 2015. The JJ stations were also stratified by depth, and consisted of 35 JJ at stratum 0 (0-50m) stations and 12 JJ at strata 1-3 (50-80m, 80-150m, and 150m+) (Table 2). Each longline station also had a jigging component (JL and JF, respectively) included to continue modifications made in 2012 as per suggestion by the Northeast Fisheries Science Center. Due to gear constraints, only 29 out of the 30 random longline stations (LL) were able to be sampled with jig gear (JL), meaning there were 29 jigging at random longline stations (JL). Furthermore, because only 9 fishermen's choice longline stations were sampled, there were 9 jigging at fishermen's choice (JF) stations sampled.). The JL stations were stratified by depth like the random longline stations; all falling into strata 1-3. Including a jigging component at each random longline (LL) and fishermen's choice (LF) station allowed for an additional 38 stations were sampled with jigging gear at LF and LL stations, creating a total of 85 stations sampled by jig gear. Atlantic cod were the only targeted groundfish species for the JJ, JL and JF, though other species including pollock and mackerel were also caught.

In 2014, there were 47 randomly stratified jig stations allocated in the survey area through strata 0-3. There were 36 jig stations in stratum 0, which made up 25.9% of sampling effort. There were four stations in stratum 1 (50-80m), four stations in stratum 2 (80-150m), and three stations in stratum 3 (150m+), comprising 2.9, 2.9, and 2.2 percent of sampling effort, respectively (Table 3). Remaining consistent with previous sampling years, there were also offshore jigging stations at all random longline stations (JL) as well as at all fishermen's choice longline stations (JF). Therefore, there were 30 jigging at random longline (JL) stations spanning strata 1-3, and 16 jigging at fishermen's choice longline stations, comprising 21.6 and 11.5 percent of total sampling effort, respectively (Table 3).

There were 48 random stratified jig stations in 2013, spanning strata 0-3. In stratum 0 (0-50m) there were 36 stations, comprising 26.5% of total sampling effort. Stratum 1 (50-80m), stratum 2 (80-150m), and stratum 3 (150+m) each had four stations, each making up 2.9 % of total sampling effort (Table 4). Finally, as with other sampling years, there were jigging components at each random longline and fishermen's choice longline station. Therefore, there were 30 jigging at random longline (JL) stations encompassing strata 1-3 that made up 22.1 percent of sampling effort (Table 4). Additionally, there were 14 jigging at fishermen's choice stations (JF) that made up 10.3 percent of total sampling effort (Table 4).

Proportion of Catch per Station

In 2016, Atlantic cod were caught at 58.3% of all random jig stations. Atlantic cod were caught at thirteen total stations in stratum 0 (0-50m), or at 36.1% of inshore jig stations: a decrease from 2015. However, Atlantic cod were caught at 66.7% of jig stations in stratum 1 (50-80m), and at 11.8% of jig stations in stratum 2 (80-150m) (Table 1). This was a dramatic increase from previous years. Finally, Atlantic cod were caught at 66.7% of jigging at fishermen's choice stations (Table 1).

In 2015 Atlantic cod were caught by jig at 31.9% of random jig stations (JJ) (Table 2). At jig stations within stratum 0 (0-50m), cod were caught at 41.2% of stations. Atlantic cod were caught at 20% of jig stations in stratum 1, and 0% in stratum 2 and 3 (Table 2). Additionally, cod were caught by jig at 6.9% of random longline stations (JL); and by jig at 44.4% of fishermen's choice stations (JF, Table 2).

In 2014 Atlantic cod were caught by jig at 29.8% of random jig stations (JJ). At stations within stratum 0 (0-50m), cod were caught at 38.9% of stations (Table 3). No cod were caught at random jig stations in stratum 1-3. Additionally, cod were caught by jig at 10.0% of random longline stations (JL); and by jig at 25.0% of fishermen’s choice stations (JF) (Table 3).

Atlantic cod were caught by jig at 19% of random jig stations (JJ) in 2013. There were 22% of stations in stratum 0 (0-50m) where cod were caught. In stratum 1 and 3 there were no cod caught, but cod were caught at 25% of stations in stratum 2 (Table 4). Additionally, Atlantic cod were caught by jig at 6.7% of random longline stations (JL); and by jig at 0% of fishermen’s choice stations (JF) (Table 4).

.The stratified random survey was only conducted between 2012 and 2016. Thus we have five years of survey abundance indices for jigging. This report will focus on the abundance index for all jigging stations from 2012-2016. Each abundance index was calculated per station type.

Mean abundance of cod at all random jig stations (JJ) decreased from 2013 to 2014, but increased from 2014-2016 (Table 5). The CV for cod at JJ stations decreased by a large amount from 2013 to 2014, but increased from 2014 to 2016 (Table 5).

The random jigging stations were then divided into inshore and offshore components for analysis. The JJ stations at stratum 0 sites were referred to as inshore stations, while JJ stations in strata 1-3 were referred to as offshore stations (JJO). First, the JJO stations were analyzed independently of jigging at longline (JL) stations. Then JJO and jigging at random longline stations (JL) were combined because they both encapsulated strata 1-3, and combining the two station types increased sample size of Atlantic cod.

Mean abundance of cod at JJ Stratum 0 decreased from 2012-2013, then sharply increased from 2013-2014 (Table 5). In 2015, the mean abundance of Atlantic cod increased slightly from 2014 (Table 5). Finally, the mean abundance of cod decreased again in 2016. While the CV was large in 2012, it decreased dramatically between 2013-2016 (Table 5).

For the offshore jigging-only stations (JJO), mean cod abundance decreased from 2013 to 2014; in 2014 there were no cod caught at any offshore jig-only stations (Table 5). However, there was a continuous increase in the mean abundance of cod at offshore jigging-only stations between 2014-2016, coupled with increasing CVs (Table 5). Once combined with the offshore jigging-at-longline sites (JL), however, the sample size increased. A similar trend was shown, with a decrease from 2013-2014 followed by an increase through 2016 (Table 5). it is important to note that CVs decreased in all years after increasing the sample size of cod at offshore jig stations.

Finally, all random jigging stations for strata 0-3 were combined and assessed (JJ+JJO+JL). Mean abundance of cod for all random jigging stations decreased from 2013 to 2014; the CV also decreased (Table 5). In 2015 and 2016, mean abundance increased with a slightly increased CV (Table 5).

The abundance indices show that jigging was highly efficient at coastal waters (i.e., Stratum 0) where fixed gear congestion makes it almost impossible for other sampling gear types (including trawl and longline). The increase in mean abundance of cod at JJ Stratum 0 stations between 2012 and 2016 is important information not previously obtainable by other survey programs in the Gulf of Maine. In addition, the CVs were relatively low, indicating a good confidence of abundance index data obtained. The abundance index highlights the importance of this inshore jigging component, especially when the survey is faced with logistical issues preventing longline sampling.

Depth was repeatedly and consistently found to be one of the most important environmental variables influencing the survey catch rates of Atlantic cod. This justifies the design of the survey as stratified by depth. Sediment and sea surface temperature were also an important factor for cod.

A large difference between the 2013 survey year versus previous years is the addition of jigging at all the longline stations. This was continued into the 2015 sampling season. For the random longline stations at which both longline and jig gear were used, cod were caught at the same number of jig and longline stations in 2013. In 2014, cod were caught only slightly less often with jig sampling than longline sampling at random longline stations where both gear types were used. In 2015, cod were caught slightly less often at random longline stations where both gear types were used. However, due to gear constraints only 29 random longline stations were able to be sampled with jig gear, while only 24 random longline stations could be sampled with both gear types.

Considering that each longline was equipped with 2000 hooks, jigging was a much more effective way to sample Atlantic cod in these random longline stations. This was helpful information, especially when considering the financial constraints in the 2016 season that led to a jigging-only sampling design. This study suggests that the longline/jig sentinel survey fishery can become an important monitoring program to collect abundance and biological data of important groundfish species in an area not well covered by other survey programs. Such information can fill the data gap in stock assessment and will become more valuable with the increased length of data time series.

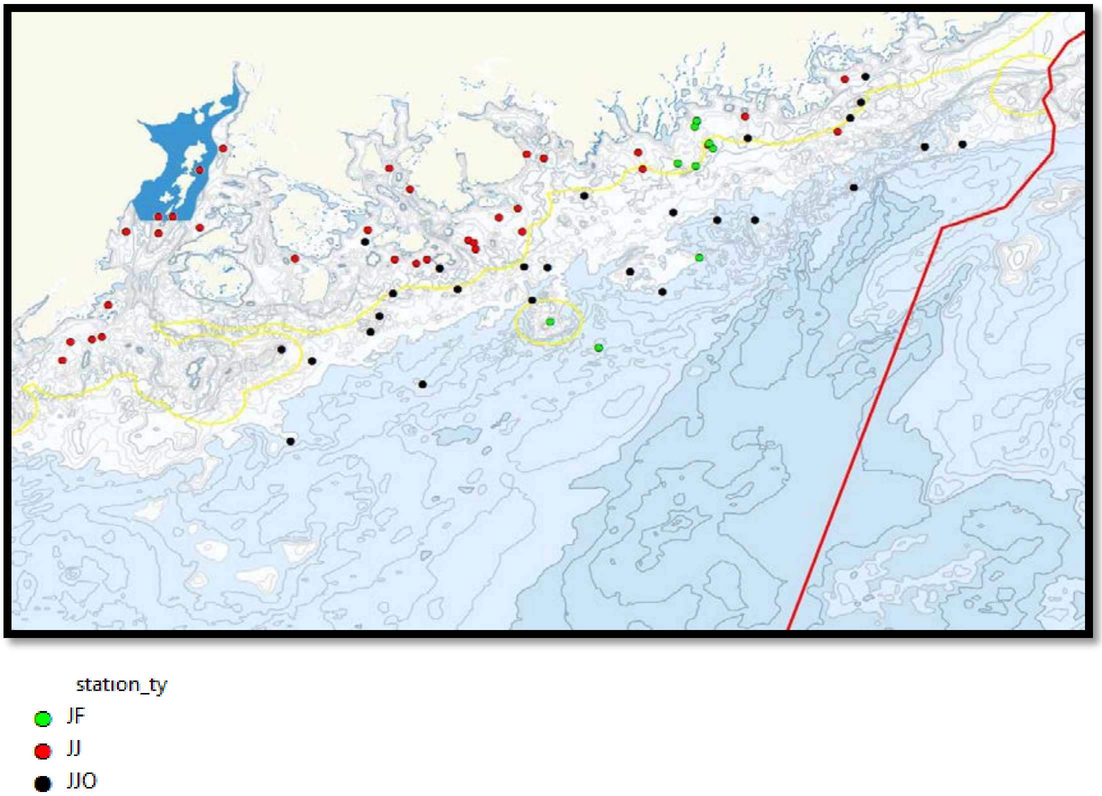

Figure 1: Survey area including 2016 sampling locations.

			Stations where species present					
	Stations		Cod					
	no.	%	no.	%	no.	%	no.	%
Jigging at jigging only station(JJ)	**62**	**87.3**						
Stratum 0 (0-50)	36	50.7	13	36.1				
Stratum1 (50-80)	9	12.7	6	66.7				
Stratum2 (80-150)	17	23.9	2	11.8				
Jigging at fisherman's choice(JF)	**9**	12.7	6	66.7				
All (cod/other species)	71							

Table 1. Breakdown of station allocations and number of stations where Atlantic cod were caught in the 2016 jig survey.

	Stations where species present											
Station Type	Stations		Cod		Cusk		White Hake		Halibut		Dogfish	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Random longline (LL)	**24**	**20.1**	**2**	**8.3**	**3**	**12.5**	**15**	**62.5**	**8**	**33.3**	**11**	**45.8**
Stratum1 (50-80)	4	3.4	0	0	0	0	0	0.0	3	12.5	1	4.2
Stratum2 (80-150)	10	8.4	1	10.0	2	20.0	5	50.0	5	50.0	3	30.0
Stratum3 (150+)	10	8.4	1	10.0	1	10.0	10	100.0	0	0.00	7	70.0
Fishermen's Choice (LF)	**9**	**7.6**	**3**	**33.3**	**2**	**22.2**	**5**	**55.5**	**2**	**22.2**	**5**	**55.5**
Jigging at jigging only station(JJ)	**47**	**39.5**	**15**	**31.9**								
Stratum 0 (0-50)	35	29.4	14	41.2								
Stratum1 (50-80)	5	4.2	1	20.0								
Stratum2 (80-150)	3	2.5	0	0								
Stratum3 (150+)	4	3.4	0	0								
Jigging at random longline (JL)	**30**	**25.2**	**2**	**6.9**								
Jigging at fisherman's choice(JF)	**9**	**7.6**	**4**	**44.4**								
All (cod/other species)	119/33	100.0	26	22.2	5	15.2	20	60.6	10	30.3	16	48.5

Table 2. Breakdown of station allocations and number of stations where groundfish species of interest were caught in the 2015 survey.

	Stations where species present											
Station Type	Stations		Cod		Cusk		White Hake		Halibut		Dogfish	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Random longline (LL)	30	22.1	5	16.7	2	6.7	19	63.3	17	56.7	13	43.3
Stratum1 (50-80)	9	6.5	0	0.0	0	0.0	0	0.0	4	44.0	0	0.0
Stratum2 (80-150)	10	7.2	2	20.0	1	10.0	7	70.0	10	100.0	3	30.0
Stratum3 (150+)	11	7.9	3	27.2	1	9.0	10	90.9	1	9.09	10	90.9
Fishermen's Choice (LF)	16	11.5	5	31.2	5	31.20	7	43.8	6	37.5	6	37.5
Jigging at jigging only station(JJ)	47	33.8	14	29.8								
Stratum 0 (0-50)	36	25.9	14	38.9								
Stratum1 (50-80)	4	2.9	0	0								
Stratum2 (80-150)	4	2.9	0	0								
Stratum3 (150+)	3	2.2	0	0								
Jigging at random longline (JL)	30	21.6	3	10.0								
Jigging at fisherman's choice(JF)	16	11.5	4	25.0								
All (cod/other species)	139/44	100.0	31	22.3	7	5.03	26	18.7	23	16.5	19	41.3

Table 3. Breakdown of station allocations and number of stations where groundfish species of interest were caught in the 2014 survey

Station Type	Stations		Cod		Cusk		White Hake		Halibut		Dogfish	
	Stations where species present											
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Random longline (LL)	30	22.1	2	6.7	2	6.7	17	56.7	11	36.7	22	73.3
Stratum1 (50-80)	5	3.7	0	0.0	0	0.0	0	0.0	4	80.0	2	40.0
Stratum2 (80-150)	12	8.8	0	0.0	2	16.7	4	33.3	5	41.7	7	58.3
Stratum3 (150+)	13	9.6	2	15.4	0	0.0	13	100.0	2	15.4	13	100.0
Fishermen's Choice (LF)	14	10.3	2	14.3	4	28.6	6	42.9	2	14.3	6	42.9
Jigging at jigging only station(JJ)	48	35.3	9	19								
Stratum 0 (0-50)	36	26.5	8	22								
Stratum1 (50-80)	4	2.9	0	0								
Stratum2 (80-150)	4	2.9	1	25								
Stratum3 (150+)	4	2.9	0	0								
Jigging at random longline (JL)	30	22.1	2	6.7								
Jigging at fisherman's choice(JF)	14	10.3	0	0								
All (cod/other species)	136/44	100.0	15	11.0	6	13.6	23	52.3	13	29.5	28	63.6

Table 4. Breakdown of station allocations and number of stations where groundfish species of interest were caught in the 2013 survey

Year/Station Type	Species							
	Cod		Cusk		White Hake		Halibut	
	mean	CV	mean	CV	mean	CV	mean	CV
2012 LL	0.15	2.89	0.56	0.19	27.52	0.12	3.90	0.095
2013 LL	0.35	0.78	0.07	0.19	32.28	0.11	1.05	0.090
2014 LL	0.21	0.24	0.04	**0.96**	16.01	0.09	2.30	0.097
2015 LL	0.12	0.71	0.20	0.26	8.77	0.03	1.2	0.11
2013 JJ	0.23	0.06						
2014 JJ	0.19	0.31						
2015 JJ	0.28	0.27						
2016 JJ	0.45	0.15						
2012 JJ Stratum 0	0.50	0.27						
2013 JJ Stratum 0	0.42	0.51						

2014 JJ Stratum 0	0.64	0.06
2015 JJ Stratum 0	0.65	0.03
2016 JJ Stratum 0	0.44	0.03
2013 JJO	0.11	0.56
2014 JJO	0.00	0.00
2015 JJO	0.21	0.49
2016 JJO	0.48	0.24
2013 JJO+JL	0.19	0.28
2014 JJO+JL	0.05	0.47
2015 JJO+JL	0.13	0.16
2016 JJO+JL	0.43	0.09

Table 5. Mean abundance and coefficient of variation (CV) of groundfish species of interest.

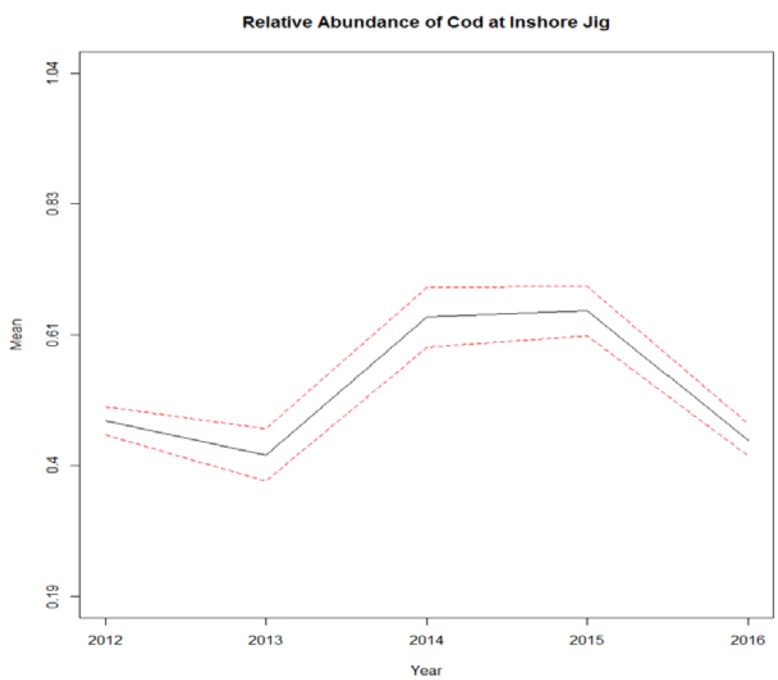

Figure 2: Relative Abundance of Atlantic cod at all Inshore Jig (JJ Stratum 0) Stations from 2012-2016.

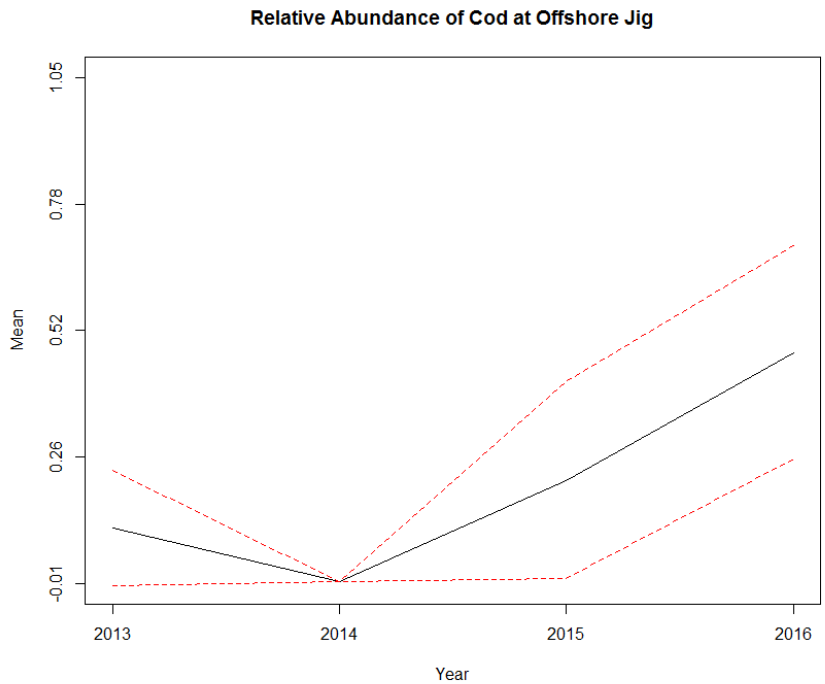

Figure 3: Relative Abundance of Atlantic cod at Offshore Jig (JJO) Stations from 2012-2016.

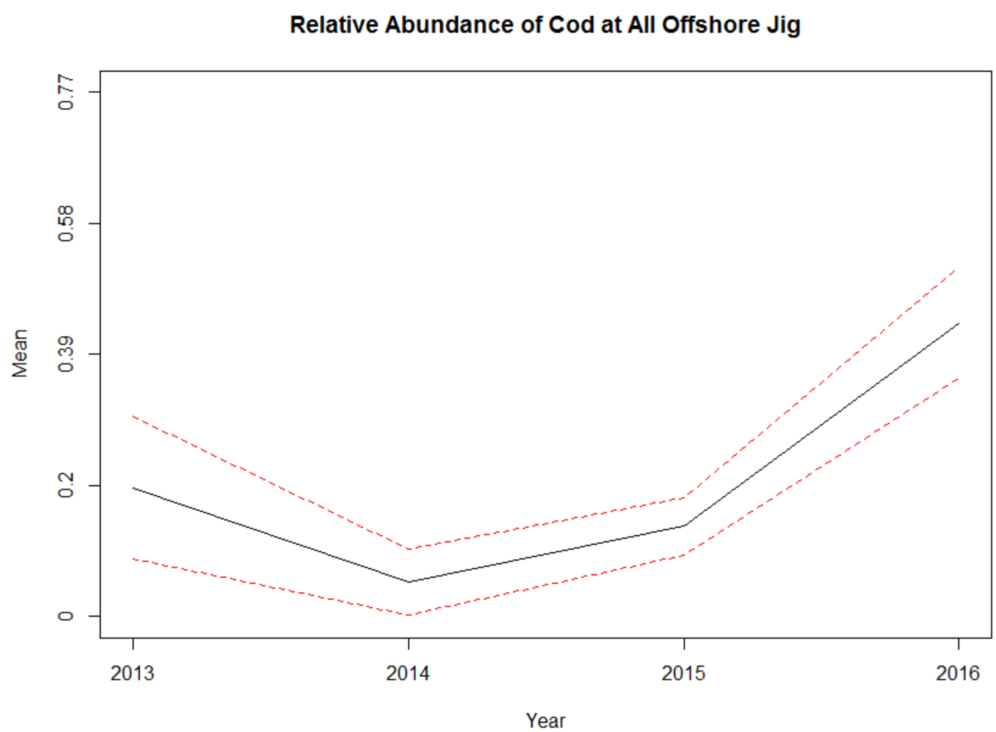

Figure 4: Relative Abundance of Atlantic Cod at all Offshore Jig (JJO+JL) Stations from 2012-2016.

Part Two: Jigging and Longline for 2010-2015

I. Executive summary

The Eastern Gulf of Maine Sentinel Survey/Fishery is a groundfish survey conducted in the summer from the western edge of Penobscot Bay to the eastern border with Canada. The survey consists of stratified random stations that are sampled with both demersal longline gear and jigging gear. A portion of the stations is also allocated for fishermen to select where they want to fish based on their knowledge of historic fishing grounds and suitable habitat. The primary objective of the survey is to provide an annual index of abundance as well as habitat preference information for groundfish species (including Atlantic cod, cusk, white hake and Atlantic halibut) in an area that was traditionally important for the commercial groundfish fishery but is not currently well covered by either commercial fisheries or other bottom-trawl – based monitoring programs. This report focuses on the most recent year of the sentinel survey/fishery in 2015, but also includes an analysis of all the survey/fishery catch data since the inception of the sentinel survey/fishery in 2010 to the most recent year 2015.

In 2015, the overall allocation of sampling effort was divided into longline and jig components that were stratified by depth. Within these two gear types, random longline stations (LL) and fishermen's choice longline stations (LF) comprised the longline portion, while jigging at jigging only stations (JJ) comprised the jig portion. Due to gear and weather-related logistical constraints, the number of random stratified fishermen's choice longline stations were decreased compared to 2014. While there were 30 LL stations picked to sample in 2015, just 24 of these stations were sampled by longline gear. The stations were stratified by three separate depths (50-80m, 80-150m, and 150m+). Additionally, though 16 LF stations were planned in 2015, only 9 of these stations were sampled. There were 47 JJ stations sampled in 2015 (Figure 1). The JJ stations were also stratified by depth, and consisted of 35 JJ at stratum 0 (0-50m) stations and 12 JJ at strata 1-3 (50-80m, 80-150m, and 150m+). Each LL and LF station also had a jigging component (JL and JF, respectively) included to continue modifications made in 2013 as per suggestion by the Northeast Fisheries Science Center. Due to gear constraints, only 29 out of the 30 random longline stations (LL) were able to be sampled with jig gear (JL), meaning there were 29 jigging at random longline stations (JL). Furthermore, because only 9 fishermen's choice longline stations were sampled, there were 9 jigging at fishermen's choice (JF) stations sampled.). The JL stations were stratified by depth like the random longline stations; all falling into strata 1-3. Including a jigging component at each random longline (LL) and fishermen's choice (LF) station allowed for an additional 38 stations were sampled with jigging gear at LF and LL stations, creating a total of 85 stations sampled by jig gear. Atlantic cod were the only targeted groundfish species for the JJ, JL and JF, though other species including pollock and mackerel were also caught. There is no LL station in Stratum 0 (0-50 m) because of a large number of fixed gear in summer in the Maine coastal waters.

In 2015 Atlantic cod were caught at a lower percentage of random longline stations than in 2014, but still higher than 2013. Additionally, Atlantic cod were caught at a higher percentage of fishermen's choice longline stations in 2015 than in both 2014 and 2013. However, Atlantic halibut were caught at a lower percentage of both random longline stations and fishermen's choice longline stations in 2015 compared to 2014, though still greater than 2013.

The stratified random survey was only conducted between 2012 and 2015. Thus we have four years of survey abundance indices for longline and jigging. Each abundance index was calculated per station type. For longline (LL), the mean abundance index of cod increased from 2012 to 2013 ,decreased from 2013 to 2014, and decreased from 2014 to 2015. (Table 16). The estimates of all four years had large CVs, making the interpretation of between-year difference difficult. The mean abundance of cusk at LL stations decreased from 2012 to 2013, decreased from 2013 to 2014, and increased from 2014 to 2015 (Table 16). All four years had large CVs. Mean abundance of white hake decreased from 2012 to 2013, decreased again from 2013 to 2014, and further decreased from 2014-2015 (Table 16). The CV in 2012 was large, slightly decreased in 2013, and then greatly decreased in 2014-2015 (Table 16). The mean abundance of Atlantic halibut at LL stations decreased from 2012 to 2013, but then more than doubled from 2013 to 2014 (Table 16). In 2015, the mean abundance for halibut decreased (Table 16). All CVs for halibut were very small. The CVs for jigging were much smaller than those for the longline.

Analysis for jigging stations in 2015 involved separating the inshore jigging (JJ at stratum 0) stations from offshore jigging at strata 1-3 (JJO). Mean abundance and CV was calculated for each. To remain consistent with previous years' analysis, however, mean abundance and CV for Atlantic cod were still calculated for each jigging component. Mean abundance of cod at all random jig stations (JJ) decreased from 2013 to 2014, but increased from 2014-2015 (Table 16). The CV for cod at JJ stations decreased by a large amount from 2013 to 2014, but increased from 2014 to 2015 (Table 16). The random jigging stations were then divided into inshore and offshore components for analysis. The JJ stations at stratum 0 sites were referred to as inshore stations, while JJ stations in strata 1-3 were referred to as offshore stations (JJO). The JJO and jigging at random longline stations (JL) were combined because they both encapsulated strata 1-3, and combining the two station types increased sample size of Atlantic cod. Mean abundance of cod at JJ Stratum 0 decreased from 2012-2013, then sharply increased from 2013-2014 (Table 16). In 2015, the mean abundance of Atlantic cod increased slightly from 2014 (Table 16). While the CV was large in 2012, it decreased dramatically in 2013, 2014, and 2015 (Table 16). For the offshore jigging stations (JJO+JL) mean cod abundance decreased from 2013 to 2014; the CV also decreased from 2013 to 2014 (Table 16). Finally, all random jigging stations for strata 0-3 were combined and assessed (JJ+JJO+JL). Mean abundance of cod for all random jigging stations decreased from 2013 to 2014; the CV also decreased (Table 16). Although cod abundance decreased over all the area from 2013 to 2014, this analysis suggests that cod abundance tended to have a different temporal pattern between inshore and offshore with cod increasing significantly inshore, but decreasing offshore from 2013 to 2014.

The abundance indices show that jigging was highly efficient at coastal waters (i.e., Stratum 0) where fixed gear congestion makes it almost impossible for other sampling gear types (including trawl and longline). The increase in mean abundance of cod at JJ Stratum 0 stations between 2012 and 2015 is important information not previously obtainable by other survey programs in the Gulf of Maine. In addition, the CVs were relatively low, indicating a good confidence of abundance index data obtained. The abundance index highlights the importance of this inshore jigging component, especially when the survey is faced with logistical issues preventing longline sampling.

To analyze the mean abundance of species at fishermen's choice (LF) stations, we used standardized catch per unit effort (CPUE). Standardization is necessary to eliminate multiple biases including fishermen knowledge of where it is most likely fish will be caught. Our fishermen were asked to choose LF stations that targeted Atlantic cod; stations could be chosen anywhere within the allotted sampling region for 2015. Trends in standardized CPUE of fishermen’s choice stations between 2010 and 2015 show a slight increase for white hake from 2010 to 2012, but a slight decrease from 2012 to 2013, followed by a decrease from 2013 to 2014 and a decrease from 2014 to 2015 (Figure 6). There was a small decrease from 2010 to 2012, a large decrease from 2012 to 2013, and a large increase from 2013 to 2014, and a large increase from 2014 to 2015 for Atlantic halibut (Figure 6). Standardized CPUE for cusk showed a decrease from 2010 to 2012 followed by an increase in 2013, a slight increase in 2014, and a minute decrease in 2015 (Figure 6). Finally, there was an increase from 2010 to 2012, a decrease in 2013, a large increase in 2014, and almost equally as large decrease in 2015 for Atlantic cod (Figure 6). Large standard errors were associated with most standardized CPUEs.

Depth was repeatedly and consistently found to be one of the most important environmental variables influencing the survey catch rates of Atlantic cod, cusk, white hake and Atlantic halibut. This justifies the design of the survey as stratified by depth. Sediment and sea surface temperature were also an important factor for some species.

A large difference between the 2013 survey year versus previous years is the addition of jigging at all the longline stations. This was continued into the 2015 sampling season. For the random longline stations at which both longline and jig gear were used, cod were caught at the same number of jig and longline stations in 2013. In 2014, cod were caught only slightly less often with jig sampling than longline sampling at random longline stations where both gear types were used. In 2015, cod were caught slightly less often at random longline stations where both gear types were used. However, due to gear constraints only 29 random longline stations were able to be sampled with jig gear, while only 24 random longline stations could be sampled with both gear types. Considering that each longline was equipped with 2000 hooks, jigging was a much more effective way to sample Atlantic cod in these random longline stations. This study suggests that the longline/jig sentinel survey fishery can become an important monitoring program to collect abundance and biological data of important groundfish species in an area not well covered by other survey programs. Such information can fill the data gap in stock assessment and will become more valuable with the increased length of data time series.

II. Introduction

The Eastern Gulf of Maine (EGOM), although not closed to groundfishing, has been perceived to have a low groundfish stock density. There is virtually no directed fishing effort for groundfish species in this region, although lobstermen have reported catching groundfish as bycatch in their traps (verified by the Maine Department of Marine Resources (DMR) sea sampling program; Kathleen Reardon and Carl Wilson, Maine DMR, West Boothbay Harbor, ME, personal communications). Although fisheries-independent survey programs such as bottom trawl surveys by the Maine DMR and National Marine Fisheries Service (NMFS) have sampling stations within the EGOM, their spatial and temporal coverage is limited. Because trawl gear use is severely limited in areas with complex bottom, trawl survey catchability for some species that reside in complex benthic habitat (e.g., cusk and halibut) tends to be low. Currently, groundfish stock assessment and the development of management strategies usually encompass the whole GOM, although the majority of fishing effort and catch occurs in the western GOM. Sparse fishery-independent as well as fishery-dependent data in the EGOM and skewed distribution of the groundfish fisheries into the WGOM may complicate the determination of the status of groundfish stocks in the GOM, potentially leading to scenarios of local stock overexploitation or inadequate management. The very low stock abundance and little fishing activity call for close monitoring of groundfish populations in the EGOM.

The longline sentinel survey/fishery[1] in the EGOM collects data important to groundfish stock assessments and management in the GOM generally, in particular for species that tend to have low catchability in Maine DMR and NMFS bottom trawl survey programs. The data collected should produce a better understanding of the spatial dynamics of groundfish stocks within the GOM and can support stock assessment for this region. The use of longline gear in the survey improves sampling effort in an area with rocky and complex bottom on which trawl gear is less efficient, and increases sampling efficiency for species that prefer complex ocean bottom (e.g., cusk and halibut).

This report provides a summary of the analysis of catch data from the first 6 seasons of the Eastern Gulf of Maine Sentinel Survey/Fishery. We used generalized linear models (GLMs) to estimate standardized catch per unit effort for the fishermen's choice stations and evaluated if various environmental variables might influence abundance indices and habitat preferences of cod, cusk, white hake and halibut for the stratified random stations. We also tested the stratified random stations with these models to make sure depth remained consistently the most significant variable to presence or abundance of these species. A high frequency of zero groundfish catch observations and other data limitations caused by possible patchy distributions of fish populations made modeling catch data difficult. While most models at this early juncture of the survey do not provide an adequate fit of the data, the majority of model results are corroborated

[1] This project is referred to as a survey/fishery because a portion of the stations are selected by fishermen (the fishery) and a portion of the stations are determined by a stratified random survey design.

by qualitative analysis of the data. As data collection continues, it is likely that future models will provide a better fit with a more robust dataset. Thus, the methods described in this report can be used in future data analysis.

III. Sentinel Survey/Fishery

III-1. Background on pilot seasons (2010, 2011)

2010 and 2011 are considered the pilot seasons for the sentinel survey/fishery. In 2010, one boat sampled 30 stations and in 2011, two boats sampled 60 stations (30 per boat). All stations in 2010 and 2011 are considered fishermen's choice stations because fishing locations were determined by the boat captains based on focus group meetings with other fishermen and sentinel fishery participants that identified historical fishing grounds. Stations were fished using a 2 nautical mile demersal longline with 2,000 hooks baited with a combination of squid and herring. In 2011, survey areas were divided into two regions: (1) between Vinalhaven and Swans Island, and (2) between Swans Island and Schoodic Ridges; to ensure even spatial coverage. All trips were observed by NOAA fisheries observers or trained research assistants.

III-2. 2012-2014 Sentinel Survey

III-2-1. 2012 longline and jigging

2012 was the third year of the sentinel survey/fishery and the first year that incorporated a stratified random survey design for a majority of the stations. Longline gear was unchanged from the previous two years (2 nautical mile longline with 2,000 hooks, baited with squid and/or herring). Target soak time was two hours although actual soak time varied depending upon tide strength and logistical constraints. Trained research assistants observed all trips.

A majority of the longline effort (62.5% of the sampling stations) was allocated to stratified random stations. The survey was stratified into three depth strata (50-80 m, 80-150 m and greater than 150 meters). Strata were determined based upon analysis of catch data from the Maine DMR inshore bottom trawl survey and the previous two years of the sentinel survey. Stations were randomly selected from these strata in proportion to the total area of the strata. The remaining 18 stations (37.5% of the effort) were allocated as fishermen's choice stations.[2] Fishermen were instructed to select stations where cod would most likely be caught based on historic fishing areas or habitat structure. All stations were sampled between July and October.

Due to fixed gear conflicts (congestion of lobster traps) that prohibit longline sampling in depths under 50 m, and at the suggestion of the Northeast Fisheries Science Center, an inshore jigging component was added to the survey in 2012. The jigging aspect of the survey was modeled after a hook and line survey used in a west coast stock assessment of Bocaccio rockfish (Harms et al., 2010). We completed 48 randomly selected stations from June through October. Five drops were completed at each station. Drop sites were selected based on assumed cod habitat or on reports from lobster fishermen who had recently caught cod bycatch in traps. Drops lasted a maximum of five minutes, starting at the time the jig hit bottom, with the anglers

[2]Fishermen's choice stations were determined in the same way as those in 2010 and 2011.

having the option of reeling in early to avoid losing fish that were already hooked. There were two anglers per boat, each fishing a rod and reel with three hooks for a total of 6 hooks and up to 10 minutes fishing time per drop. We evaluated survey design, examining our choice of depth stratification and the effect of soak time on catch rates. Based on the evaluation, we concluded that the choice of depth in the stratified random survey design was appropriate.

III-2.2. 2013-2015 longline and jigging

2015 was the sixth year of the sentinel survey/fishery and the fourth year a stratified random survey design was incorporated for a majority of the stations. Longline gear was unchanged from the previous five years (2 nautical mile longline with 2,000 hooks, baited with squid and/or herring). Target soak time was two hours although actual soak time varied depending upon tide strength and logistical constraints. Trained research assistants observed all trips.

The overall allocation of sampling effort in 2015 was consistent with the 2013-2014 sampling effort. That effort was modified based on feedback we had and based on the analysis we had done with the 2012 and 2013 survey data. A breakdown of station allocations for 2015 is shown in Table 1. A major change we made in 2013 compared to the 2012 design was that we added jigging at each type of station. Therefore, in 2014-2015 each type of station also had a jigging component.

Logistical issues in the 2015 season including weather, bait acquisition, and fishermen participation somewhat limited sampling in 2015. Sampling in 2015 consisted of the following three types of stations: (1) stratified random longline stations (LL; 24 stations over 3 strata); (2) Fishermen's choice longline stations (LF; 9 stations); and (3) jigging stations (JJ; 47 stations over 4 strata with 35 stations in the shallowest stratum (inshore stratum for jigging, 0-50 m; Table 1). In addition to these types of stations, jigging was also applied to stratified longline stations (referred to as JL) and fishermen's choice longline stations (referred to as JF), which adds an additional 39 (i.e., 30 LL stations and 9 LF stations; Table 1) jigging stations in 2015. Atlantic cod were the only targeted groundfish species for the JJ, JL and JF (Table 1). The configuration and operation of longline and jigging gear followed those in 2014. The locations of actual survey stations for 2015 are shown in Figure 1.

Table 1. Breakdown of station allocations and number of stations where groundfish species of interest were caught in the 2014 survey.

	Stations where species present												
Station Type	Stations		Cod		Cusk		White Hake		Halibut		Dogfish		
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	
Random longline (LL)	**24**	**20.3**	**2**	**8.3**	**3**	**12.5**	**15**	**62.5**	**8**	**33.3**	**11**	**45.8**	
Stratum1 (50-80)	4	3.3	0	0	0	0	0	0.0	3	12.5	1	4.2	
Stratum2 (80-150)	10	8.5	1	10.0	2	20.0	5	50.0	5	50.0	3	30.0	
Stratum3 (150+)	10	8.5	1	10.0	1	10.0	10	100.0	0	0.00	7	70.0	
Fishermen's Choice (LF)	**9**	**7.6**	**3**	**33.3**	**2**	**22.2**	**5**	**55.5**	**2**	**22.2**	**5**	**55.5**	
Jigging at jigging only station(JJ)	**47**	**39.8**	**15**	**31.9**									
Stratum 0 (0-50)	35	29.2	14	41.2									
Stratum1 (50-80)	5	4.2	1	20.0									
Stratum2 (80-150)	3	2.5	0	0									
Stratum3 (150+)	4	3.3	0	0									
Jigging at random longline (JL)	**29**	**24.6**	**2**	**6.9**									
Jigging at fisherman's choice(JF)	**9**	**7.6**	**4**	**44.4**									
All (cod/other species)	118/33	100.0	26	22.2	5	15.2	20	60.6	10	30.3	16	48.5	

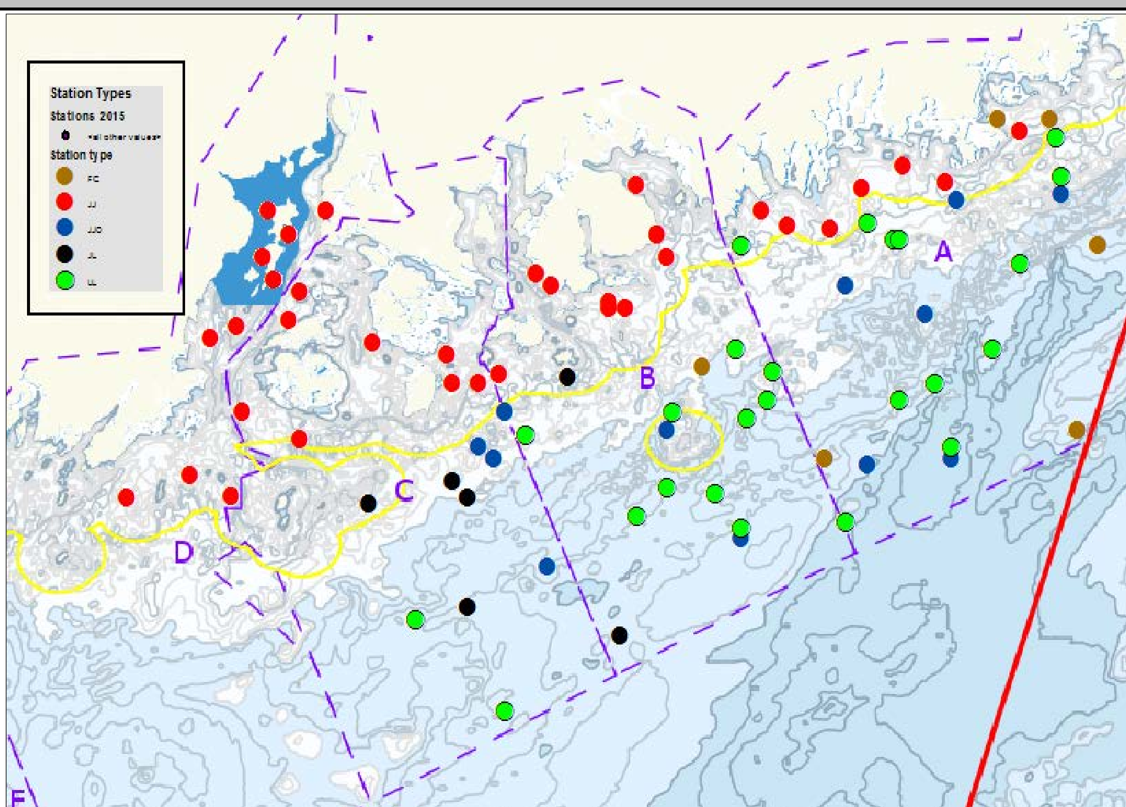

Figure 1. Survey area including 2015 sampling locations.

III-3. Data Limitations

Catch data from the sentinel survey contain a high frequency of zero observations. This is particularly true for cod and cusk abundance. Modeling such data with many zero catches is complex because there are more zeros in the response variable than expected if a Poisson or negative binomial distribution is assumed. Ignoring the excessive number of zeros can create bias in parameter estimates and standard errors.

Additionally, due to the changes in design and oversight, data collection has varied over the first four years of the survey. During the pilot years (2010-2011) observed sediment type was not collected. For these years, USGS data (Poppe et al., 2005) were used to determine sediment type. However, the distance between the sample sites of this data is much greater than that of the sentinel survey. In a recent comparison between the USGS data and observed data in the survey, we found that the USGS sediment data are not at all reliable on the scale relevant to this survey program. Thus, we decided to use sediment data observed during the survey that is only available in the 2012-2014 surveys. Bottom temperature was not recorded or only partially recorded for 2010-2013 Additionally, the number of stations sampled varies each year. These limitations will be minimized in the future as the survey design and protocol are now standardized. For example, sampling for 2014-2015 included reliable bottom temperature and sediment data observations. As the survey progresses, there will be enough reliable bottom temperature data to do adequate analysis.

III-4. General Methods

We used generalized linear models (GLMs) with the number of individuals caught as the response variable in order to: 1) develop a standardized CPUE using data from the fishermen's choice stations, 2) develop an abundance index using data from the random stations and 3) model groundfish habitat preferences using data from all station types. Possible explanatory variables included in models were: year, depth, sea surface temperature, sediment type, longitude and latitude. Due to the high frequency of zero observations and overdispersion in the response we used zero inflated models to avoid violating assumptions implicit when using standard distributions (Martin et al., 2005). Often these violations are addressed by log transforming the response variable; however, this is not ideal for data with many zeroes for two reasons: 1) in order to log transform the zeroes an arbitrary number must first be added to the data, 2) the data are then dominated by the new value of the transformed zero observations (Hinton and Maunder, 2003). Zero-inflated models are an alternative way to address this issue and are becoming an increasingly popular choice for modeling abundance in many ecological fields (Martin et al., 2005) as well as longline fisheries data (Ichinokawa et al., 2012; Minami et al., 2007; Walsh et al., 2013).

There are two approaches to modeling data with a high frequency of zeros. The first is a zero altered or hurdle model. Zero altered models consist of two parts. The first part is a binomial model that models the probability of a positive response. The second part of the model is a count process that models the non-zero responses. This count process is zero truncated, thus there is some threshold or “hurdle” that must be reached (as modeled in the binomial portion) in order to have a positive response. Once this hurdle is reached the count process is modeled (Zurr et al., 2009).

Zero inflated or mixture models are similar to zero altered models in that they have two components; however they differ in the way that they treat zero observations. The binomial process models the probability of observing a “false zero” (no fish were detected but the conditions are suitable for fish to be caught) and the probability of a positive count or true zero (no fish were detected because the conditions are such that they will never occur). Thus, the count process includes both zero and non-zero values and is modeled with a negative binomial or Poisson distribution. We use zero-inflated models to model catch data from the sentinel survey because they include zero observations in the count process of the model. Thus they incorporate circumstances where the environment is appropriate for a positive catch to occur but no fish is caught.

Zero inflated models were produced using the pscl package (Zeileis et al., 2008). We also developed more traditional (not zero-inflated) GLMs for datasets with fewer than 50% zero observations. All models were produced in the statistical program R (R Core Team 2012).

Initial models were fit for each dataset that included all the explanatory variables which may influence the fish distribution and abundance (year, depth, sea surface temperature, sediment type, longitude and latitude). Limited spatio-temporal coverage of the sentinel survey resulted in limited contrast in the data. As a result, some explanatory variables might not be suitable for inclusion in the model. Terms which were not statistically significant ($p>0.10$) were dropped until a model was found in which all terms were significant. Parameters in the binomial portion of the model may not be significant at $p<0.10$ for species with lower catch rates (cod, cusk) due to lack of reference. In these instances, parameters were selected for the binomial model that produced the most significant count model. As a diagnostic, Pearson’s residuals of selected models were analyzed for normality and these residuals were plotted against each explanatory variable and the fitted values. Predicted values from the model were plotted against the original data to determine if the model provided an adequate fit.

We focus our analyses on four species: Atlantic cod, cusk, white hake and Atlantic halibut, because of their importance and relevance.

III-4-1: Standardized Catch Per Unit of Effort

Catch data from the sentinel survey in 2010, 2011 and the fishermen’s choice stations in 2012-2015 are considered fisheries dependent data because fishing locations were chosen by fishermen. Fisheries catch per unit of effort (CPUE) data can be used in the stock assessment process to augment fisheries independent survey abundance index data. One major issue when using fisheries CPUE data in stock assessment is that the assumption that catch rates are related to stock abundance may be violated (Hilborn and Walters, 1992), because catch rates are often influenced by other variables that are not related to stock abundance such as fishermen’s skill and knowledge and location of fishing. In order to use fisheries CPUE data as an index of abundance, the effect of these other variables, other than stock abundance, that impact catch rates must be removed through standardization (Maunder and Punt, 2004). The most common method used for this process of CPUE standardization is through the use of generalized linear models (Maunder and Punt, 2004).

Models were generated for each species using data from all fishermen's choice stations. Data from 2010 was the reference year. Year is included as a categorical variable in the count part of the model (even when not statistically significant) in order to account for annual variation. Standardized CPUE is calculated as the year coefficient of the count portion of the model.

III-4-2. Abundance index from stratified random survey stations

Like the 2012-2014 surveys, the 2015 survey also included stratified random stations for both jig and longline (Table 1). In post-survey analysis after the 2012-2015 survey seasons, we found that depth was the only factor that may significantly influence catch rates at this type of station. Because we used depth in the stratification, the influence of depth is considered. A large number of 0 values spurred us to use the delta mean method to estimate abundance for the stratified random stations. The mean abundance for each species of interest per strata was calculated using weighted area data, then summed per station type.

Additionally, the inshore random jigging stations (JJ at Stratum 0) were analyzed separately from the offshore (JJO) jigging stations for 2012-2015. The delta mean method was used to account for the large number of zeros, and the mean abundance of species of interest was calculated using the same method described above.

III-4-2-1. Model-based Approach

We used GLMs to model abundance and remove variability that is a function of other independent variables. This method is the same as the approach used to standardize CPUE discussed earlier.

III-4-2-2. Design-based Approach

Sophisticated model-based approaches can be useful to standardize abundance indices, however there are many assumptions that must be fulfilled in order to benefit from their use (ICES, 2004). Comparisons of model-based approaches often show limited improvement over simpler methods of abundance estimates (ICES, 2004). For the longline catch, all GLMs demonstrate quantitatively that depth is consistently the most significant variable in determining abundance. The influence of depth is accounted for in the survey design, so a stratified mean abundance and variance can be used for an abundance index that still includes this important variable. For the jigging data, no environmental variables were found to significantly affect abundance so mean and variance can be used for the abundance index. Mean abundance and variance were calculated for both the longline and jig data using the delta approach (Pennington, 1983) using the fishmethods package (Nelson, 2013) in R.

III-4-3. Habitat Modeling

GLMs are often used in order to quantify and predict habitat use in relation to environmental variables (Guisan and Zimmermann, 2000). These habitat preferences are often used to identify critical habitat and examine spatial distribution of species. We use GLMs to model habitat preferences using the complete data set of the sentinel survey (all years, both station types) from 2010 to 2015.

Data limitations (described earlier) make the modeling process difficult, so an entirely quantitative approach cannot be used or unrealistic models may result. Therefore, terms that were statistically significant but where the direction or size of the effect did not make biological sense were, after careful consideration, dropped based on the author's prior knowledge of the data and biological literature. The diagnostics of these models show that the fit is not adequate to be used for predictive purposes, however qualitative analysis displays similar results. To illustrate these patterns, we plotted the proportion of total stations where each species of interest were caught in relation to different environmental variables.

IV. Results and discussion

IV-1. Survey catch statistics

The percentage of a key fish species caught, shown by gear type and stations type is presented in Table 1. Cod were caught by jig at a high percentage of jig stations, 31.9%, (i.e., JJ; Table 1). However, the percentage of survey longline stations where cod were caught by longline (i.e., LL) was 8.3%, about a fourth the percentage of stations where cod were caught by jig. In addition, the percentage of survey longline stations sampled by jig where cod were caught (i.e., JL) (Table 1) was 6.9%, still less than cod caught by longline at random longline stations. This suggests that sampling efficiency of jig and longline for cod is not very similar in the 2015 survey season.

In addition, there is a drastic difference between percentage of stations where cod were caught at inshore jigging stations (JJ at Stratum 0; Table 1) stations compared to the offshore jigging stations (strata 1-3, JJO and JL; Table 1). Cod were caught at 41.2% of inshore jigging stations (JJ at Stratum 0; Table 1), while only 26.9% of all total offshore jigging stations reported cod catch (strata 1-3, JJO and JL; Table 1). This difference suggests that the inshore jigging stations sample the area more efficiently than offshore jigging stations, especially in depths between 0-50 meters.

Fishermen's choice stations (i.e., FL) tended to have a higher percentage of stations where cod, cusk, and halibut were caught, compared to the random longline survey stations (i.e., LL) (Table 1). However, white hake and dogfish were caught at a higher percentage of the LL stations than the FL stations, suggesting that these species were sampled more efficiently at the random longline stations compared to the FL stations (Table 1).

The catch at the LL, FL, JJ, JL, and JF is presented in Table 2 for weights and in Table 3 for numbers. Dogfish were the most caught species, followed by white hake (Tables 2 and 3).

	LL	FL	JJ	JL	JF	Total all Stations(lbs)
Cod	**6.5**	**22.65**	42.3	4.55	18.25	94.25
Cusk	20	14	0	5.25	0	39.25
White Hake	708.3	227.65	0	0	4	939.95
Halibut	525.75	93	0	0	0	618.75
Dogfish	2748.63	1582.36	0	0	0	4330.99
Other	179.3	45.55	23.7	1.25	10.45	260.25

Most cod were caught at the JJ stations, with more cod caught at inshore jigging stations.

Table 2. Total weights (in pounds) for species of interest caught during the 2014 sentinel survey by station type.

Table 3. Total catch (in #) for species of interest caught during sentinel survey by station type.

	LL	FL	JJ	JL	JF	Total all Station
Cod	3	10	22	3	8	46
Cusk	5	2	0	1	0	8
White hake	215	83	0	0	1	299
Halibut	27	6	0	0	0	33
Dogfish	594	499	0	0	0	1093
Other	195	25	28	6	7	261

IV-2. Standardized catch per unit of effort (CPUE) for stations of fishermen's choice

IV-2-1. Catch of Atlantic cod, cusk, white hake, and Atlantic halibut

IV-2-1-1. COD

Cod were captured at 33.3% of all fishermen's choice stations in 2015 (Table 4). On average from 2010 to 2015, cod were caught at 18.6% of fishermen's choice stations (Table 4). Frequency of cod abundance per station from 2010 to 2015 is shown in Figure 2. *Depth was not significant in the count or zero inflated portion of the model. This implies that depth had no impact on the presence or absence of co, and no impact on abundance once cod were present (Table 5). However, this needs to be interpreted with caution because of limited depth ranges covered by fishermen's choice stations.

Table 4. Number and percent of stations where cod were caught at fishermen's choice stations each year.

	Total	Cod	
Year(s)	no.	no.	%
2010	30	3	10
2011	60	9	15
2012	16	5	31
2013	14	2	14
2014	16	5	31
2015	9	3	33.3
2010-2015	145	27	18.6

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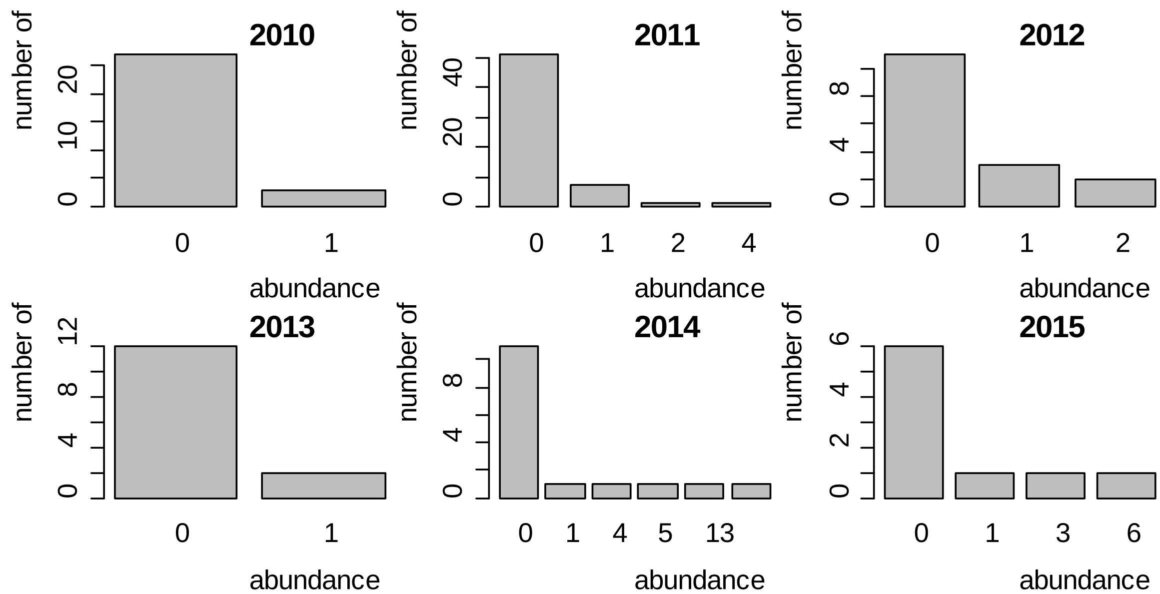


Figure 1. Abundance frequency of cod caught at fisherman's choice stations.

Count model (negbin with log link)

Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-3.36	1.91	-1.57	0.08
year2011	0.87	0.73	1.20	0.23
year2012	1.93	0.93	2.10	0.04
year2013	0.59	1.08	0.55	0.59
year2014	3.35	0.78	4.27	0.00
Year2015	2.02	0.87	1.06	0.02
depth	0.01	0.01	1.02	0.40
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	0.546	2.03	0.27	0.79

depth	-0.003	0.01	-0.26	0.79

Table 5. Cod ZINB standardized CPUE model results

IV-2-1-2. CUSK

Cusk were caught at 22.2% of the fishermen's choice stations in 2015. On average from 2010 to 2015, cusk were caught at 21% of fishermen's choice stations (Table 6). Frequency of cusk abundance per station is shown in Figure 3. Depth was not significant in the zero portion of the model, meaning depth had no impact on abundance of cusk (Table 7). This needs to be interpreted with caution because of limited depth ranges covered by fishermen's choice stations.

Table 6. Number and percent of stations where cusk were caught at fishermen's choice stations each year.

	Total	Cusk	
Year(s)	no.	no.	%
2010	30	5	17
2011	60	13	22
2012	16	0	0
2013	14	4	29
2014	16	6	38
2015	9	2	22.2
2010-2015	145	30	21

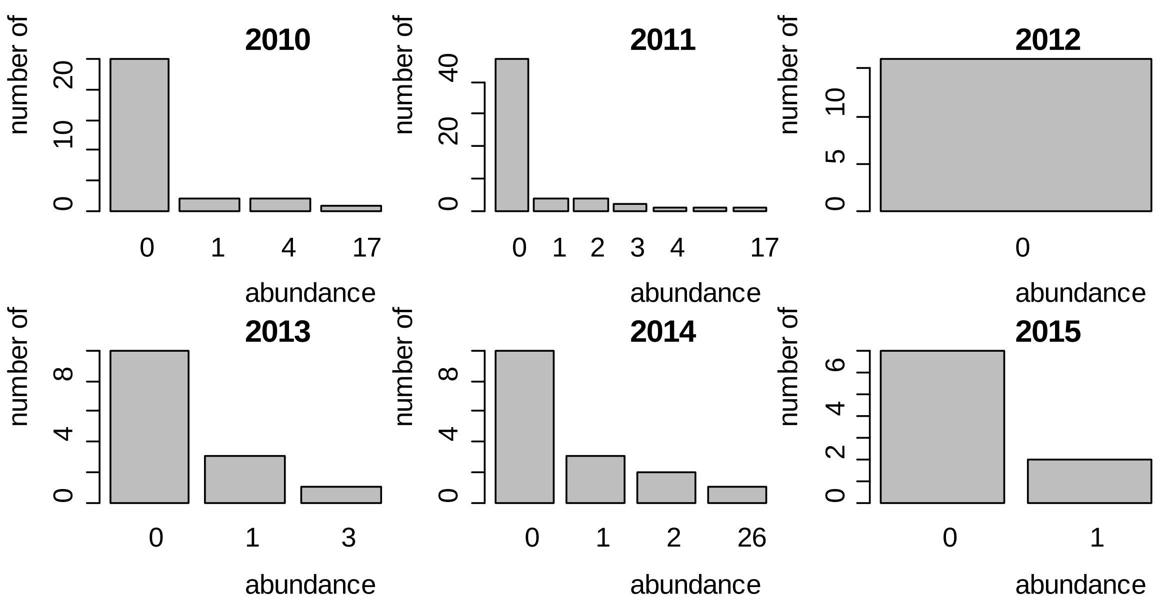


Figure 2. Abundance frequency of cusk caught at fishermen's choice stations.

Table 7. Cusk ZINB standardized CPUE model results

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-0.67	0.77	-0.86	0.39
year2011	0.53	1.00	0.53	0.60
year2012	-16.51	1604.71	-0.010	0.60
year2013	0.16	1.24	0.128	0.90
year2014	1.54	1.04	1.47	0.14
latitude	-0.79	0.52	-1.51	0.13
longitude	0.50	0.47	1.05	0.141
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	122.07	468.01	0.26	0.80
Depth	-3.13	11.91	-0.26	0.79

IV-2-1-3. WHITE HAKE

White hake were caught at 55.5% of the fishermen’s choice stations in 2015, and on average white hake were caught in 44.1% of fishermen’s choice stations from 2010 to 2015 (Table 8). Frequency of white hake abundance per station is shown in Figure 4. Depth had a positive impact on white hake presence in the count model with an increase in presence at deeper stations, and a negative impact on abundance in the zero-inflated portion of the model. (Table 9).

Table 8. Number and percent of stations where white hake were caught at fishermen's choice stations each year.

	Total	**White Hake**	
Year(s)	no.	no.	%
2010	30	9	30
2011	60	31	52
2012	16	8	50
2013	14	6	43
2014	16	7	44
2015	9	5	55.5
2010-2015	145	64	44.1

Figure 3. Abundance frequency of white hake caught at fishermen's choice stations.

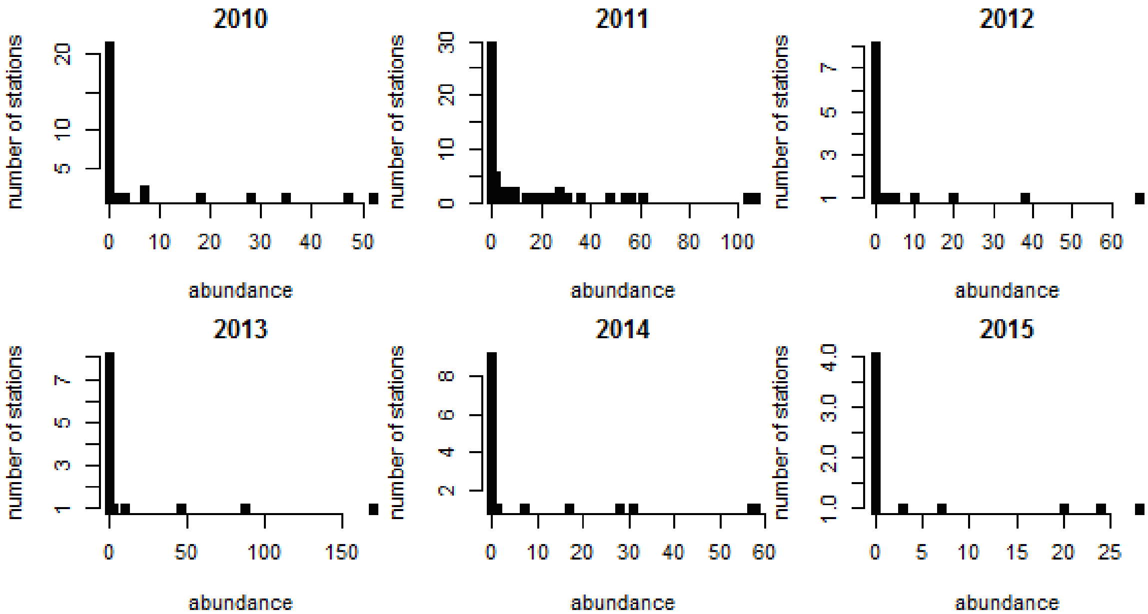


Table 9. White Hake ZINB standardized CPUE model results.

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-1.86	0.88	-2.11	0.03
year2011	1.23	0.51	2.44	0.015
year2012	1.13	0.64	1.78	0.075
year2013	1.59	0.67	2.36	0.001
year2014	1.40	0.61	2.30	0.022
year2015	-1.78	1.05	-1.69	0.091
depth	0.02	0.004	5.37	0.000
latitude	-0.41	0.24	--1.68	0.094
longitude	0.36	0.34	1.05	0.300
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	3.24	0.85	3.81	0.000
depth	-0.03	0.006	-4.58	0.000

IV-2-1-4. HALIBUT

Halibut were caught at 22.2% of the fishermen's choice stations in 2015. On average, halibut were caught at 44.1% of fishermen's choice stations from 2010 to 2015 (Table 10). Frequency of halibut abundance per station is shown in Figure 5. Depth was significant in the zero-inflation portion of the model, implying that depth impacted halibut abundance if they were present. The results should be interpreted with caution because of the limited depths sampled by fishermen at these stations. (Table 11).

Table 10. Number and percent of stations where halibut were caught at fishermen's choice stations each year.

	Total	Halibut	
Year(s)	no.	no.	%
2010	30	12	40
2011	60	31	52
2012	16	11	69
2013	14	2	14
2014	16	6	38
2015	9	2	22.2
2010-2015	145	64	44.1

Figure 4. Abundance frequency of halibut caught at fishermen's choice stations.

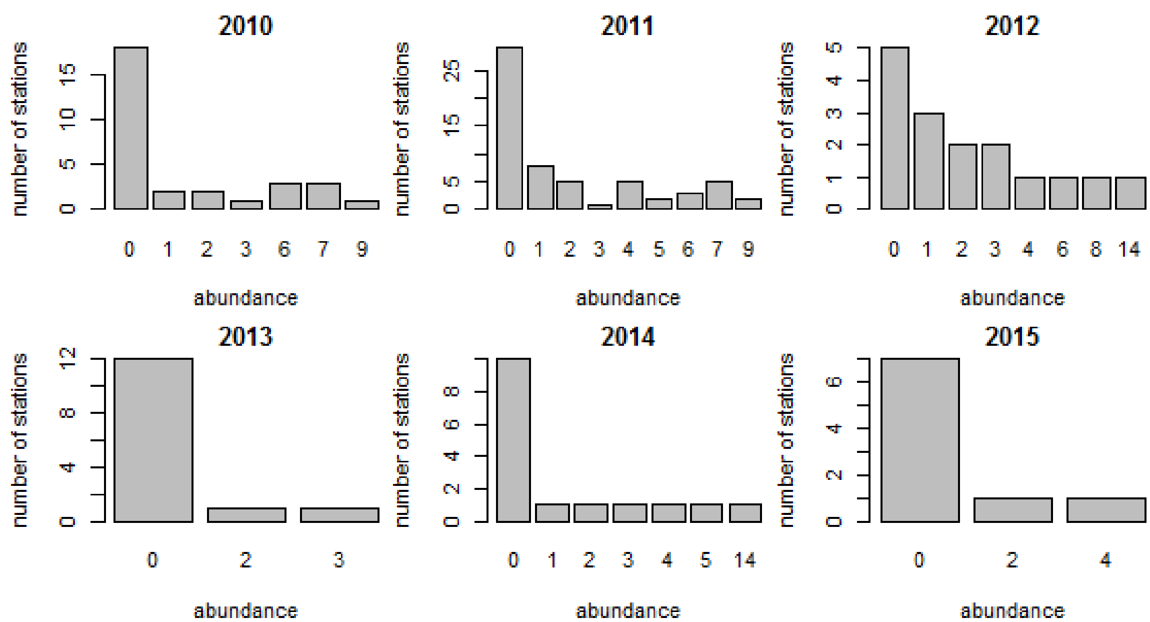


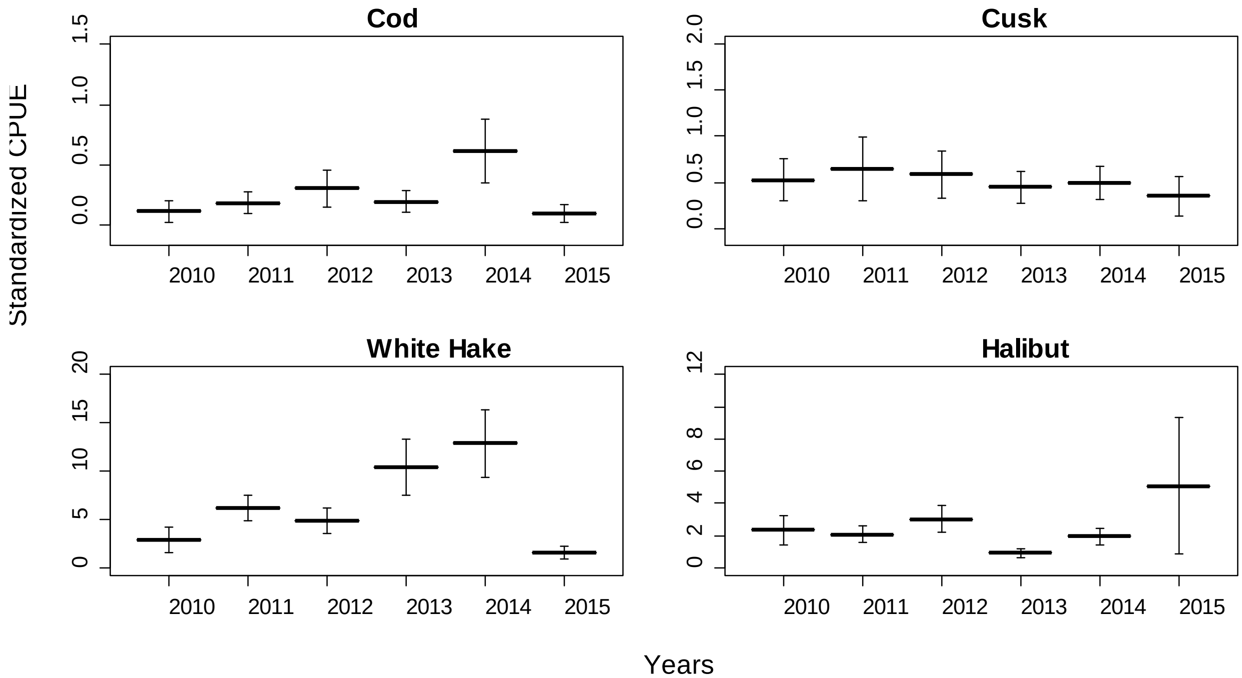
Table 11. Halibut ZINB standardized CPUE model results

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	0.48	0.72	0.67	0.51
year2011	-0.27	0.39	-0.69	0.49
year2012	-0.32	0.46	-0.70	0.48
year2013	-2.20	0.65	-3.37	0.000
year2014	-0.55	0.51	-1.08	0.28
year2015	-0.09	0.01	1.09	0.28
Depth	0.01	0.01	1.50	0.13
latitude	0.70	0.38	1.84	0.07
longitude	-0.31	0.31	-1.00	0.32
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-8.70	2.82	-3.09	0.002
Depth	0.06	0.02	3.43	0.001

IV-2-2. Standardized CPUE for Atlantic cod, cusk, white hake, and halibut

Standardized CPUE for cod shows an increasing trend from 2010 to 2012, a decrease in 2013 followed by a large increase in 2014, then a sharp decrease in 2015. Standardized CPUE of cusk shows an approximately similar trend between 2010-2015. Standardized CPUE of white hake shows an increase from 2010 to 2014, but decrease in 2015. Standardized CPUE of halibut showed a similarity from 2010 to 2012, then an increase between 2013-2015 (Fig. 6).

Figure 6. Standardized CPUEs for the four key species derived from fishermen's choice's stations from 2010 to 2015.



IV-3. Estimation of abundance index from stratified random stations

IV-3-1: Model-based abundance index

<u>IV-3-1-1. COD</u>

IV-3-1-1-a. Longline (LL)

A total number of 3 cod were caught at 2 of the random longline stations (LL) in 2015 (Table 1, Figure 7). Due to this low catch rate, there is not enough contrast in the data to quantitatively model abundance. The 2 LL stations where cod were caught were in two of the three deep strata.

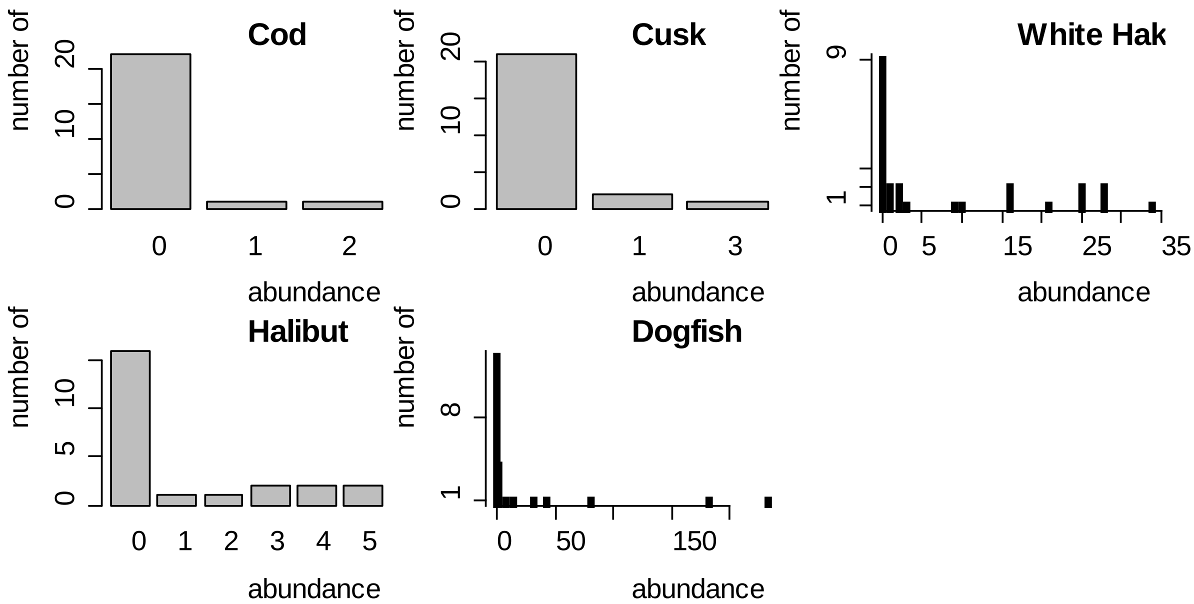


Figure 7. Abundance frequency of cod, cusk, white hake and halibut caught by longline at the stratified random longline stations (LL) in 2015.

IV-3-1-1-b-1. Jigging at longline stations (JL)

For the 24 stratified random longline stations, we also applied jigging in 2015 in addition to longline. Due to logistical constraints only 24 longline stations out of 30 were sampled with longline gear; however all stations were sampled with jig gear. Cod were only caught at 2 of the 29 stations, which is the same number of stations where cod were caught with longline (Table 1). This suggests that for these stations jigging had a somewhat higher sampling efficiency, because of the relative differences between high sampling coverage from longline gear (2000 hooks) and jig gear (6 hooks). Given the low catch rate we used binomial GLMs with a logit link function to determine if any independent variables had a significant effect on the presence or absence of cod. No variables were significant.

IV-3-1-1-b-2. Jigging at jig stations (JJ)

In the 2015 survey, we allocated 47 stations for jigging based on a stratified random survey design. Most jig stations are in inshore shallow water (0-50 meters) where longlining cannot be done because of congestion of fixed gear (lobster traps) during the survey season. Cod were caught at 15 of the 47 stations in 2015, representing 31.9% of all the jigging stations (Table 1).

IV-3-1-1-c. Longline and Jigging combined for all stratified random stations

In order to increase our dataset we modeled cod abundance from random longline stations and jigging stations in 2015 using a categorical variable for gear type. Depth had a positive relationship with cod abundance, though it was not significant in the count model. (Table 12). Sediment was also not significant. This was similar to the results we derived for the fishermen's choice stations, in which we found a positive relationship between cod catch and depth (see Table 5). The combined data of longline and jigging stations have a much larger depth range from shallow waters (jigging stratum <=50 m) to deep waters (>150 m for stratum 3; Table 1). Thus, the analysis of jig-longline survey stations is likely to yield more reliable results. However, because longline gear is only deployed in the first three strata, inshore jig gear should not be included in analysis.

Table 12. Cod ZINB abundance index model results

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	1.144	0.00	1.28	0.20
depth	0.00	0.00	0.09	0.92
sediment mix	-1.05	0.00	-1.96	0.05
sediment soft	-0.00	0.76	-0.37	0.71
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	1.93	0.93	2.09	0.04
year2015	-2.4	1.02	-2.4	0.02
Gear type LL	-0.82	-0.80	-1.03	0.31

<u>IV-3-1-2. CUSK</u>

Cusk were caught at 12.5% of random longline stations in 2015 (Table 1).The count model shows that depth had a negative and significant impact on the presence of cusk at random longline stations (Table 13). Therefore, the count portion of the model shows that cod presence will decrease with depth.

Table 13. Cusk ZINB abundance index model results

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
year2015	-0.93	0.73	-1.27	0.20
depth	-0.02	0.008	-2.87	0.004
SST	-0.02	0.17	-0.12	0.90
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	5.28	2.83	1.87	0.06
depth	-0.05	0.03	-1.57	0.12

IV-3-1-3. WHITE HAKE

White hake were caught by longline at about 62.5% of the random longline stations (Table 1). The count model shows depth to be positively and significantly related to the presence of white hake (Table 14).

Table 14. White Hake GLM abundance index model results.

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-0.48	0.75	-0.64	0.52
depth	0.01	0.004	2.87	0.00
Sediment mix	1.83	0.53	3.44	0.00
Sediment soft	2.06	0.54	3.80	0.00
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	8.07	4.71	1.71	0.09
year2015	1.67	1.32	1.26	0.21
depth	-0.09	0.05	-1.84	0.07

IV-3-1-4. HALIBUT

Halibut were caught at 33.3% of the random longline stations (Table 1). Halibut were caught at 3 out of 4 stations in the second-deepest stratum (50-80m), and 5 out of 10 stations in the next deepest stratum (80-150m; Table 1). However, halibut were caught at 0 out of 10 stations in the deepest stratum (150m+; Table 1). Depth has a positive and significant impact on halibut abundance as shown by the zero-inflated portion of the model (Table 15).

Table 15. Halibut ZINB abundance index model results

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	2.43	0.51	4.76	0.00
year2015	-0.84	0.46	-1.80	0.07
depth	-0.01	0.01	-1.60	0.11
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-7.96	3.4	-2.34	0.02
depth	0.05	0.02	2.58	0.01

IV-3-2. Design-based Approach

The influence of depth is accounted for in the survey design; thus a stratified mean abundance and variance can be used for an abundance index. Mean abundance and variance were calculated for both the longline and jig data using the delta approach. The stratified random survey was only conducted between 2012 -2015. Thus we have four years of survey abundance indices for longline and jigging. The estimates of delta mean and CV of species for 2012-2015 were included in Table 16.

Analysis for jigging stations in 2014 was conducted slightly differently than in previous years; the inshore jigging (JJ at Stratum 0) stations were separated from offshore jigging at strata 1-3 (JJO) and mean abundance and CV was calculated for each. To remain consistent with previous years' analysis, however, mean abundance and CV for Atlantic cod were still calculated for each jigging component. This method was held consistent for 2015 data analysis. Mean abundance of cod at random jig stations (JJ) decreased from 2013 to 2014 (Table 16). The CV for cod at JJ stations decreased by a large amount from 2013 to 2014 (Table 16). The random jigging stations were then divided into inshore and offshore components for analysis. The JJ stations at stratum 0 sites were referred to inshore stations, while JJ stations in strata 1-3 were referred to offshore stations (JJO). The JJO and jigging at random longline (JL) stations were combined because they both encapsulated strata 1-3, and combining the two station types increased sample size of Atlantic cod. Mean abundance of cod at JJ Stratum 0 decreased from 2012-2013, sharply increased from 2013-2014, then slightly increased from 2014-2015 (Table 16). While the CV was large in 2012, it decreased dramatically between 2013-2015 (Table 16).

For the offshore jigging stations (JJO+JL) mean cod abundance decreased from 2013 to 2015; the CV increased from 2013 to 2014 then decreased in 2015 (Table 16). Finally, all random jigging stations for strata 0-3 were combined and assessed (JJ+JJO+JL). Mean abundance of cod for all random jigging stations decreased from 2013 to 2014 then increased in 2015; the CV also decreased from 2013 to 2014 then slightly increased in 2015 (Table 16). Although cod abundance decreased over all the area from 2013 to 2014, this analysis suggests that cod abundance tended to have a different temporal pattern between inshore and offshore with cod increasing significantly inshore, but decreasing offshore at random jigging stations from 2013 to 2015.

Analysis for longline stations between 2012-2015 was conducted for cod, cusk, white hake, and halibut. Mean abundance and CV were calculated per year for each species. Mean abundance for cod at random longline stations increased between 2012 and 2013, then decreased from 2013-2015 (Table 16). The CVs associated with the mean abundance of cod were large, increasing between 2012 and 2013, decreasing in 2014, then drastically increasing in 2015 (Table 16). Mean abundance for cusk at random longline stations decreased between 2012-2014, then increased in 2015 (Table 16). There were large CVs associated with mean abundance of cusk, increasing in 2014 drastically then decreasing in 2015 (Table 16). The mean abundance of white hake decreased between 2012-2015, and had decreasing CVs between 2012-2015 (Table 16). The mean abundance of halibut at random longline stations decreased between 2012-2013, increased between 2013-2014, then decreased in 2015 (Table 16). The CVs associated with mean abundance of halibut at random longline stations also decreased between 2012-2013, increased between 2013-2014, then decreased in 2015 (Table 16).

Year/Station Type	Species							
	Cod		Cusk		White Hake		Halibut	
	mean	CV	mean	CV	mean	CV	mean	CV
2012 LL	0.15	2.89	0.56	0.19	27.52	0.12	3.90	0.095
2013 LL	0.35	0.78	0.07	0.19	32.28	0.11	1.05	0.090
2014 LL	0.21	0.24	0.04	**0.96**	16.01	0.09	2.30	0.097
2015 LL	0.12	0.71	0.20	0.26	8.77	0.03	1.2	0.11
2013 JJ	1.17	0.62						
2014 JJ	0.64	0.04						
2015 JJ	1.13	0.43						
2012 JJ Stratum 0	0.50	0.27						
2013 JJ Stratum 0	0.42	0.51						
2014 JJ Stratum 0	0.64	0.06						
2015 JJ Stratum 0	0.65	0.03						
2013 JJO+JL	0.22	0.38						
2014 JJO+JL	0.19	0.11						
2015 JJO+JL	0.22	0.06						
2013 JJ+JJO+JL	0.21	0.57						
2014 JJ+JJO+JL	0.04	0.36						
2015 JJ+JJO+JL	0.22	0.16						

Table 16. Delta mean and coefficient of variation (CV) for survey abundance index of longline and jig for the four groundfish species.

IV-4. Habitat Modeling

We included all the longline catch in habitat modeling, but no jigging. This is because we did not have reliable substrate data for specific jig drop sites prior to 2014. For all the four species of interest, the majority of stations had 0 catch. However, over the last six years, we did see some large catch for all the four species, even though they were not frequent. This was especially true at the fishermen's choice longline stations (FL); but because of limited habitat types sampled at those stations it is important to interpret the results with caution. Based on model diagnostics, the best fitting models did not adequately predict abundance based on environmental variables. However, plots of abundance against certain environmental variables do show qualitative patterns that corroborate the model results. These results show patterns in catch that could be useful in determining preferred habitat for these species in the survey area.

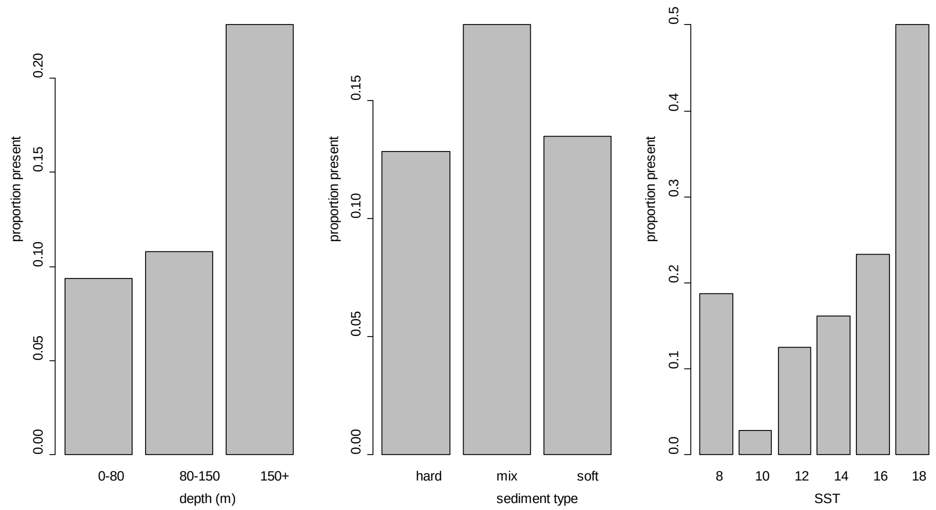
IV-4-1. COD

The distribution of cod abundance with respect to depth and observed sediment type and depth and sea-surface temperature is shown in Figure 8. Cod presence tended to increase with depth (Fig. 8), and depth was significant (Table 17). Cod presence also tended to increase with SST, and SST was significant (Figure 8, Table 17). Because we only made observations of sediment type from 2012-2015, the observations of sediment type were used from those years. These relationships were documented in the Gulf of Maine as cod were described to occur on mixed sediments and deeper slopes of ledges (Bigelow and Schroeder, 1953).

Table 17. Cod ZINB habitat model results

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-6.90	1.44	-4.77	0.00
SST	0.31	0.10	3.14	0.00
depth	0.01	0.01	1.84	0.07
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-5.64	60.25	-0.09	0.93

Figure 8. Proportion of stations where cod was caught within each depth stratum and at different sediment types and at different temperatures.



IV-4-2 CUSK

Models showed that soft and mixed sediments were significant in predicting presence of cusk and had a negative effect (Table 18). Qualitative analysis corroborates this relationship, as cusk were caught more frequently on the hardest bottom (Figure 9). Qualitative analysis also shows cusk were caught most often at the mid to deepest depths and hard bottom(Figure 9). These observations are documented in the literature as well, which describes cusk as generally found in deeper water and on hard or rough bottom with rocks, pebbles and boulders, or occasionally mud, but that they avoid sandy bottom (Bigelow and Schroeder 1953).

Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-0.85	0.80	-1.05	0.29
depth	0.00	0.00	0.90	0.37
obs_sediment_hard	0.67	0.68	0.98	0.33
obs_sediment_mix	-1.37	0.52	-2.65	0.01
obs_sediment_soft	-2.49	0.71	-3.51	0.00

Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-8.54	98.82	-0.10	0.93

Figure 9. Proportion of stations where cusk were caught within each depth stratum, and by each sediment type (hard, mix, and soft) observed in the survey

Table 18. **Cusk ZINB habitat model results.**

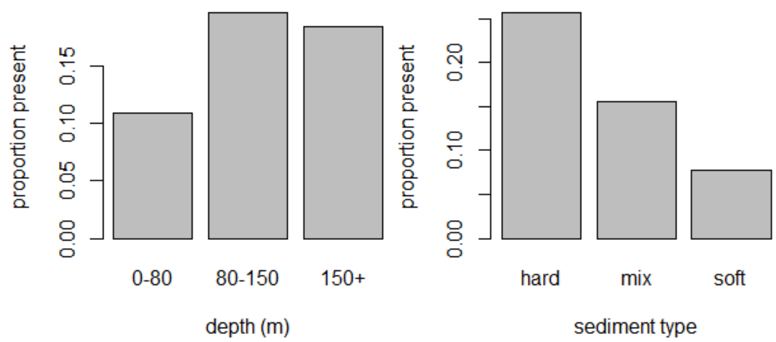


Figure 9. Proportion of stations where cusk were caught within each depth stratum, and by each sediment type (hard, mix, and soft) observed in the survey

IV-4-3. WHITE HAKE

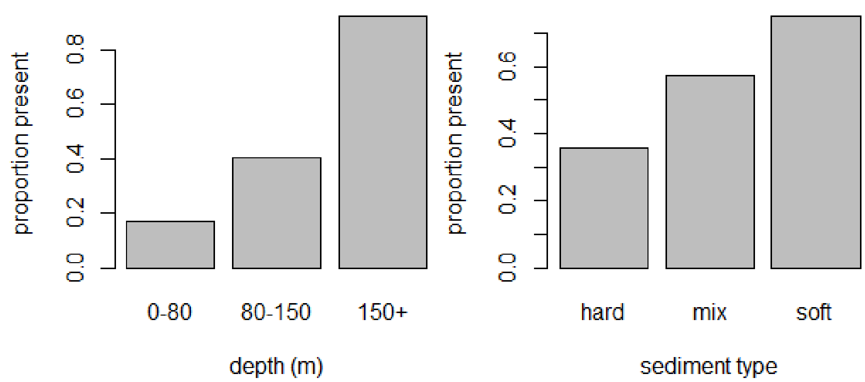
Models showed that depth was the most significant explanatory variable for predicting the presence of white hake, with a higher likelihood of presence at deeper stations (Table 19). Soft bottom was significant (Table 19) and had the highest catch (Figure 10). The relationship between white hake abundance and depth has been observed with larger fish occurring at deeper depths in the summer (Bigelow and Schroeder, 1953). Qualitative analysis demonstrates this relationship with depth as well as the relationship between white hake abundance and observed sediment type (Figure 10). This preference of white hake for soft, muddy bottom can also be seen in the literature (Bigelow and Schroeder 1953).

Table 19. White Hake GLM habitat model results

Count model (negbin with log link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	0.58	0.52	1.12	0.26
depth	0.01	0.00	4.92	0.00
obs_sediment_hard	-0.13	0.40	-0.32	0.75
obs_sediment_mix	0.39	0.28	1.38	0.17
obs_sediment_soft	0.58	0.29	2.03	0.04
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	3.93	0.62	6.33	0.00

depth	-0.04	0.01	-6.76	0.00

Figure 10. Proportion of stations where white hake was caught within each depth stratum, and by each sediment type (hard, mix, and soft) observed in the survey.



IV-4-4. HALIBUT

Models showed that depth was significant in the zero-inflated portion of the model (Table 20). Halibut have been observed to move inshore in the summer months in the Gulf of Maine (Bigelow and Schroeder, 1953) and this distribution was also seen qualitatively in the sentinel survey catch, showing a higher proportion of halibut presence in the first two strata. (Figure 11).

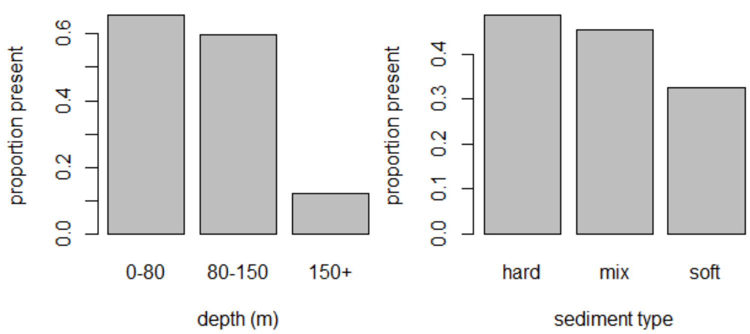
Table 20. Halibut ZINB habitat model results.

Count model (negbin with log link)

Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	1.16	0.18	6.51	0.00
obs_sediment_hard	-0.14	0.29	-0.49	0.62

obs_sediment_mix	0.09	0.25	0.35	0.73
obs_sediment_soft	-0.29	0.32	-0.95	0.36
Zero-inflation model (binomial with logit link)				
Covariate	Coefficient	SE	z-value	Pr(>|z|)
(Intercept)	-8.17	1.96	-4.17	0.00
depth	0.06	0.01	4.60	0.00

Figure 11. Proportion of stations where halibut was caught within each depth stratum and by each sediment type (hard, mix, and soft) observed in the survey.



IV-5. Survey evaluation and soak time

We evaluated the survey design and impacts of soak time in the 2012-2015 survey and concluded that the analysis confirms that depth is the most consistently significant variable in determining abundance of cod, cusk, white hake and halibut. This verifies that stratification by depth is appropriate for this survey. Depth strata were determined based on analysis of average coefficient of variation of length and abundance. Plots of average coefficient of variation by strata of 2015 catch show similar patterns suggesting strata depth are divided properly. In order to preserve continuity in the survey, strata should not be adjusted unless there are drastic changes in patterns of these CVs.

Catch rates are generally expected to increase at a decreasing rate with soak time, however this relationship is often found to be not significant in models, particularly with respect to cod (Lambert, 1994; Lokkeborg and Pina, 1997). Additionally, studies have found that most fish are caught between 2 and 2.5 hours and that fish loss due to predation may occur with additional soak time (Lokkeborg and Pina, 1997; Ogura et al., 1980). In 2012, 2013, and 2014 the target soak time for the sentinel survey was two hours (from the beginning of gear set to the beginning of gear haul). Due to weather conditions, strong tides or fishing schedules the target was not always met.

We used GLMs to analyze the relationship between soak time and catch abundance in the 2012- 2014 sentinel surveys. Due to low catch rates for cod and cusk, zero inflated negative binomial models were used on these species. These models show no significant relationship between catch abundance and soak time in either the binomial or count process for either cod or cusk. Traditional GLMs with a negative binomial distribution were used for halibut and white hake and show no significant relationship between catch abundance and soak time. This suggests that our target soak time of two hours is sufficient.

IV-6. Other Data Collected

In addition to the data analyzed in this report we collect biological information including weight and length of every species we catch as well as environmental data such as sea surface temperature, bottom temperature, observed sediment type and weather observations. Specific fishing information such as gear used, soak time, latitude and longitude of gear set and haul back are also recorded. All data is collected according to NMFS sampling protocol. We also collect specific data to collaborate with other research projects. We have provided fin clips to Dr. Adrienne Kovach at the University of New Hampshire for her work identifying genetic stock structure of Atlantic cod. We also provide photos of cod to Dr. Graham Sherwood at the Gulf of Maine Research Institute (GMRI) for his work on cod morphometrics. Beginning in 2013 we have collected otoliths from cod and cusk and are beginning to collaborate with Dr. Lisa Kerr at GMRI who will use otolith chemistry to address the question of whether cod in the eastern Gulf of Maine are distinct from cod in the western Gulf of Maine.

V. Acknowledgements

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VI. Literature Cited

Bigelow, H.B., Schroeder, W.C., 1953. Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service.

Guisan, A., Zimmermann, N.E., 2000. Predictive habitat distribution models in ecology. Ecological Modeling 135, 147–186.

Harms, J.H., Wallace, J.R., Stewart, I.J., 2010. Analysis of fishery-independent hook and line-based data for use in the stock assessment of bocaccio rockfish (*Sebastes paucispinis*). Fisheries Research 106, 298–309.

Hilborn, R., Walters, C.J., 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. Kluwer Academic Publishers, Norwell, MA.

Hinton, M.G., Maunder, M.N., 2003. Methods for standardizing CPUE and how to select among them.

ICES, 2004. Report of the Workshop on Survey Design and Data Analysis (WKSAD). Aberdeen, UK.

Ichinokawa, M., Oshima, K., Takeuchi, Y., 2012. Abundance indices of young Pacific bluefin tuna derived from catch-and-effort data of troll fisheries in various regions of Japan.

Lambert, T.C., 1994. The First Report of the 4vn Sentinel Survey. Dartmouth, Nova Scotia Canada.

Lokkeborg, S., Pina, T., 1997. Effects of setting time, setting direction and soak time on longline catch rates 32, 213–222.

Martin, T.G., Wintle, A., Rhodes, J.R., Field, A., Low-choy, S.J., 2005. Zero tolerance ecology : improving ecological inference by modeling the source of zero observations. Ecology 1235–1246.

Maunder, Mark N., Punt, A.E., 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70, 141–159.

Minami, M., Lennert-Cody, C.E., Gao, W., Roman-Verdesoto, M., 2007. Modeling shark bycatch: The zero-inflated negative binomial regression model with smoothing. Fisheries Research 84, 210–221.

Nelson, G.A., 2013. fishmethods: Fisheries Methods and Models in R.

Ogura, M., Arimoto, T., Inoue, Y., 1980. Influence of the immersion time on the hooking rate of a small bottom longline in coastal waters. Bull. Jpn. Sot. Scientific Fish 46, 963–966.

Pennington, M., 1983. Efficient Estimators of Abundance, for Fish and Plankton Surveys. Biometrics 39, 281–286.
Poppe, L., Williams, S., Paskevich, V., 2005. USGS east-coast sediment analysis: procedures, database, and GIS data.
Walsh, W.A., Chang, Y., Lee, H., 2013. Catch Statistics , Size Compositions , and CPUE Standardizations for Blue Marlin Makaira nigricans in the Hawaii-based Pelagic Longline Fishery in 16–23.
Zeileis, A., Kleiber, C., Jackman, S., 2008. Regression Models for Count Data in R. Journal of Statistical Software 27.
Zurr, A., Ieno, E.N., Walker, N., Saveliev, A.A., Smith, G.M., 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, New York.